Filtration

F. E. Vey

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A Thesis Presented by

FRANK EUGENE VEY

to the

PRESIDENT and FACULTY

of

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For the Degree

of

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Having Completed the Prescribed Course of Study in

Civil Engineering.

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Chicago, Illinois.

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PREFACE.

In choosing a proper subject for a thesis, a good amount of care was exercised. Three kinds of theses were recognized; theoretical, experimental, and general designing. Of these three it was thought that the last would be the most profitable.

To what branch should the subject pertain? The four leading branches are, railway, bridge, hydraulic, and sanitary engineering. Railway engineering has been one branch in which the writer little expects to specialize. The theory and practice of bridge designing has been thoroughly entered into at Armour, and, outside of actual erection, little additional could be gained by a thesis in that subject. As for a thesis on bridge erection, it was anticipated that to procure the required data (e.g. Plans of bridge, borings of site, etc.) would cause much trouble. The choice then lay between hydraulic and sanitary engineering, and in these, one subject in each was eliminated by choosing that subject for draughting room work. They were a design for a water system for a small town and a sewer system for the same place.

The three subjects nominated were: The design of a large storage reservoir, entailing the plans of a dam and controlling works; the development of water-power; and a filtration system.

It has been the writer's intention from the first, that whatever subject should be taken up, its design should be dependent upon actual conditions and assumptions should only be made when

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lack of time does not permit of a proper investigation of the phase under consideration. Then again the locality that the subject should be designed for, should be so situated, that the writer could get there in person and look over the ground. The Des Plaines River would fit the first three nominations, the Calumet would fit the first and last, while a north shore town would fit the last.

It was afterward learned that the engineers of the Drainage District had experienced much trouble in the study of the control of the Des Plaines River and on this score, it was thought not advisable to adopt this subject, for, in the comparatively short time the writer could spend in the work, a solution that would be satisfactory, could hardly be made. Besides, there was the question of securing the proper data. The subject of water-power was then dropped, although at first it seemed the most likely subject to be chosen.

Blue Island, the largest town on the Calumet, had no official contour map, and as there had been a recent change of engineers, it was not easy to make arrangements for the use of the level notes of the town.

On the other hand, the writer had secured a map of Wilmette containing street intersection elevations and also a five-foot contour map of the surrounding country. There was no chance for an impounding reservoir, for we have one, many times larger than necessary, in Lake Michigan.

The writer then chose the subject of filtration. The reasons for including this subject in those nominated, will appear in the

closure of this thesis.

The first work done on the thesis, was the construction of a bibliography. The writer had spent fifteen or twenty hours on it, when the library administration came to his assistance and made out another, and more complete one.

Some of the works that have been read on the subject are:

Filtration of Public Water Supplies--Hazen (1896)

Water Filtration Works--Fuertes (1900)

Public Water Supplies--Turneau and Russell

Volumes of Engineering News

" " " Record

1900 and 1903 Edition of the Transactions of the American Society of Civil Engineers

Reports of the Massachusetts State Board of Health

Journal of Society of Western Engineers

" " the Franklin Institute.

The first two books were read through critically. In the Engineering Record, the articles to which most attention was paid were "The Mechanical Filters of the Hackensack Water Co." Vol. 50 p. 572, and "Anderson Filtration Plant."

In the Tr. Am.Soc. C.E., 1900, Hazen's discussion on his design of the Albany slow sand filters, was read carefully and a brief taken of it. Briefs were also taken of Weston's experiments on a mechanical filter and of a discussion before the Society Of Filtration of Water for Public Use. Fuller's discussion of his design of the mechanical filtration works at Little Falls, in the 1900 edition of Tr. Am. Soc. C,E., was accorded the same treatment as

was Hazen's discussion.

It would be out of place to make a comment on all the articles read.

The writing of this thesis is arranged under four heads; preface, introduction, general description of plant, and appendix.

The preface is designed for explanation which cannot well appear in the other parts of the thesis to indicate the system used in the writing. In the first part it shows that some method has been employed in the choosing of a proper subject. A short bibliography follows with a brief comment on some of the references. It is then proposed to discuss the arrangement of the introduction, that of the general description of plant, and that of the appendix.

In the introduction, the subject of purification, is discussed in a somewhat brief and technical manner. Not all the methods are touched upon. The prime idea in each is given.

In discussing the English or slow sand filter, the simple theory is explained in as few words as possible. The method of operation is then taken up. Appurtenances that accompany the filters then follow. A few rules of good practice are given. Credit is given to the station at Lawrence, Mass. for their good work. By this time , it is thought a fair idea of slow sand filtration is obtained so that the theory is again entered into but in a much more extended manner. The introduction of the process in England and America is given, with a short account of the development at the present day in America. Mention is also made of a few prelim-

inary processes that tend to increase the output of the plant.

In treating mechanical filters, a short comparison is made between them and slow filters. The theory and method of filtration then follow. A discussion of the chemicals used, their action, and their application is then made. An explanation of the operation of the older type of mechanical filter is followed by the development in the method of cleaning in the newer type. The controller and some of the modern improvements are then pointed out. The operation of the latest type is then taken up in detail. The pressure type of filter is hardly touched upon, acknowledging the writer's ignorance of them. In pointing out the necessity of a study of the supply before deciding upon the manner of purification, a comparison of the slow sand and mechanical filter is again made. This part of the thesis ends by a discussion as to the proper name of each type of filter.

The next part, Description of Plant, is headed by a note calling attention to the condition under which the drawings were made, the conventions in them, and the manner of locating the parts described. It may be well to read the note at this point.

A general aspect of the points to be supplied, of the location. and kind of plant, and of the building and its contents, are first given.

The handling of four principal quantities treated--water, wash-water, waste-water, and air--are taken at their source and followed through their various courses. Explanation of bypassing follows that of the source effected thereby. Following this, is

the operation of a single filter, it being considered that the reader, by this time, has a fair idea of the functions of the various parts of filter.

The drain of the clear well is necessarily explained in conjunction with the pump supply. Following this, is the drainage system of the reservoir, tanks, and pipes.

A fifth principal quantity, chemical, is explained in the same manner as are the other four.

The other main parts of the building are then touched upon as they may better be explained in conjunction with their design. The parts having no connection directly with those explained are left for the last subjects. This includes the points of entrance to the various reservoirs so that they may be cleaned.

The object of this part has been to acquaint the reader with the filtration plant in particular, and to indicate its relation to the other installations of the building, viz., electric generating plant and pumping station. The writer can then take up the component parts of the filter plant, and discuss them in an independent manner.

INTRODUCTION.

Filtration, as applied to water, is the process by which a water passing through a media, is relieved of some or all of the substances foreign to it.

Underground waters in most cases are Nature's own filtered water. For, as the water falls on the surface of the earth, it becomes charged with humous acids and eroded materials, and as it sinks into the earth, passing between the constituent particles, the suspended matter is caught between these interstices. In some cases the water is changed chemically due to the material it passes through.

An imitation of this natural process has been carried out by Richter in Sweden. The underground water supply was chemically undesirable. Large beds were dug between the supply wells and the source of the underground water (in this case, a mountain). In each bed was placed a thick layer of sand. River water was let into the beds so that its head was just enough to overcome that due to the underground water. This kept the underground water out of the supply wells while they were being filled by the water of these beds, passing just as the underground waters had done. Generally one month is spent in the transit of the water a distance of 400 feet.

In the socalled filter galleries, we have another imitation of Nature. For the most part, underground water will flow toward and into a river. But in some cases, where one river is higher than another, water will flow from the higher river to the lower.

If now, a trench is dug that is lower than the river bottom, and contains a porous material, water will pass from the river into it or it may intercept the ground water as it passes toward the river. So we have either a trench along the river filled with sand or crib at the bottom of a river over which is placed stone, gravel, and then sand.

These methods so far described, are special methods of filtration. It will, perhaps, be better to finish the discussion of the special methods of filtration and some of the other prominent other methods of water purification and leave the two main methods of filtration for the last.

The Worms method of filtration (named after its author) consists of forcing water through a hollow cell or pane of fused sand and glass, the water percolating from both sides into the central hollow space from where it is conveyed to the clear well. These panes are about 3' square, 8" thich, including a 1" hollow space. These panes are arranged in rows, tiers, and sections. In cleaning them, a jet of water is played against them. This filter has found favor in some places of Europe because of its ease of operation and its saving of space over the slow sand filter.

Decantation or sedimentation, is one method of purification. It consists of allowing the water to stand a sufficient length of time and then drawing the upper portion off, or of having the water fed in at one end and at the same time drawn off at the other so as to have a continuous flow, but so slow as to allow most of the suspended materials to settle. St. Louis is supplied by the latter

method.

Many supplies, especially underground water, have been objectionable because of the iron in solution. This iron is precipitated by the aeration method, which consists of breaking the water into small sheets or sprays so that air can get at all sides of small bodies of the water. The oxygen of the air is absorbed and the iron is precipitated. The precipitate may either be allowed to settle and the clear water then drawn off, or the water may be cleared by passing through filters.

The Anderson process has been tried in several places in Europe. It consists of allowing the water to come in contact with metallic iron, and iron carbonate is formed. This is oxydized, passing into an insoluble ferric cloride, which is then filtered out of the water.

The apparatus consists of a rotating perforated cylinder which keeps the broken scrap iron stirred and the water in falling from the perforations is aerated. This process works well when small quantities of turbid water are to be handled, but on a large scale, the chemical action is not completed. It can be seen that the latter is but an extension of the former process in that here the water is first charged with iron and then aerated.

The two methods of filtration that are most extensively used today, are the slow sand or English filters, and the rapid, or mechanical, or American filters.

The English filter itself consists of a water-tight basin(no limit to size, it depending on local conditions) containing a layer of sand from 3' to 5' supported by 8" to 12" of gravel; beneath or

in this gravel is a suitable system of drainage.

Water may be pumped directly into this basin from its source, but is more often taken from a reservoir where some degree of subsidence has taken place. The water is allowed to pass through the sand until a sufficient thickness of skin or film of the suspended substances has covered the top of the sand. Water passing through this film, is retained in a clear well or filtered water reservoir, the previous water having been wasted.

This film has interstices so small as to retain minute bacteria and other suspended matters. The thickness of the film increases with the amount of water filtered and we have an increasing loss of head. When this becomes so great (or the filters so clogged) that the required rate of filtration can no longer be maintained, the filtration must be stopped and this film removed. This process is called "cleaning the filters" and at such times, 1-2" to 3-4" depth is removed from the top. This dirty sand is reçovered by washing in some special machine and is not replaced until the thickness of the bed is reduced some 2' or 3'. The length of operation depends upon the turbidity of the water and the rate of filtration and usually ranges from twelve to thirty days. The water, generally, has to run to waste for about three days before the desired quality of filtration is obtained, so that the filter is out of operation from five days and upward.

The appurtenances that usually accompany the modern filters are overflow arrangements in sedimentation reservoir, filter and clear well, inlet and outlet regulation in the filter, rate-of-filtration

devices, pressure or head recording instruments, and venturi meters.

In order to protect the filter from the cold in winter, a masonry cover (concrete, plain or reinforced, brick, or stone) is built over the filters high enough above them to give sufficient air space when the latter are filled with water, and high enough to allow a man to work with comfort when the filter is dry. The ground arch for all but reinforced concrete, has been the most popular type of construction. On the roof is placed a few feet of earth to act as a blanket and is properly drained. Manholes are placed at convenient points, usually at the crest of each second dome. These will admit the sand and gravel during construction, and light, during cleaning. It is claimed by many that the quality of the filtrates is improved because of the reduction of the growth of algae. By a few others, the reverse is claimed.

The water must never enter the filter in such a manner as to disturb the upper surface of the sand. This is accomplished by allowing it to enter a small chamber or box in the filter and overflow.

The surface of the sand, during cleaning, is removed with a shovel and collected in small heaps which are carted out with a wheelbarrow outside of the filter into a court either on or between the filters and deposited to await the sand cleaner. A sand ejector has recently been perfected so that cartage by wheelbarrow is suspended. All surfaces of the basins and pillars in contact with the sand, either have ledges, so that the sand may rest on them, or are roughened either by sanding them, or by using a rough brush on the cement-plastered surface. The object of this, is to prevent the water from descending to the floor between the wall and the sand.

The gravel along the walls and around the pillars, for a distance of two or more feet, is omitted, the sand touching the floor. Should cracks appear in the wall, the water would find easy access to the floor; in order to reach the drain, it must pass through the sand lying on the floor.

To the experimental station at Lawrence, Mass. are due most of the research data on slow sand filtration. This work is under the direction of the State Board of Health. They have found, for example, that sudden changes of rate of filtration, and high rates are to the detriment of the quality of the filtrate. (At this point it may be said that designers strive to have the same rate of filtration at all points, obtaining the same by grading the size of drains directly as the distance their volume must travel to outlet (or grading them directly as the loss of head their contents suffer in transit to the outlet). If the rate were not uniform in all parts of the filter, then at the points of high rate, we would obtain an inferior quality of filtrate which would soon clog, and the filter, to produce the same average rate as before, having now a smaller area, would have to increase its rate at other points, and again we would obtain an inferior quality.)

Their definition for effective size as given out by the station is "The size of grain such that 10% by weight of the particles are smaller and 90% larger than itself is considered to be 'effective size.'"

Their definition for uniformity coeficient is, "The uniformity coeficient is the ratio of the size of grain which has 60% of the

sample finer than itself to the size which has 10% finer than itself."

Graded sizes of sand are used for a bed because the interstices therein are smaller than a sand of uniform size. Definitions as to the above are required to classify the sand taken as a whole. In the matter of operation, they have found that when a filter has become clogged, scratching its surface with a short toothed rake, will allow filtration to continue. By this means the period between actual cleaning is prolonged.

There is as yet, no general accepted theory of filtration. It has been contended by many engineers that the whole action of filtration takes place in the film formation on the sand and that the latter serves only to support the film. The sand, though, acts more than a support; it assists in filtration. This can be shown by the fact that a new filter will not attain its highest efficiency until it has been in service for a long period; also that some filters have been clogged down to the bottom.

The original idea of filtration was that of straining so as to remove the turbidity. It was soon found that the water was improved chemically also. With the birth and rise of bacteriology, came a great change in the idea of filtration. A water that had formerly satisfied the physical and chemical standards, must now satisfy the bacteriological standard. In some cases the physical is disregarded. Thus a water may have a bad odor or color, or both, and still be a permissable water. Filtration plants of each kind are guaged by their bacteriological results and are built accordingly.

For some waters, the slow sand filters will remove odor, color,

and taste, besides producing marked chemical changes. This may be explained by the fact that all the above mentioned, may be due to the minute suspended particles which are strained out, or to the septic action that takes place in the film. In some cases odor may be eliminated by aeration.

In 1829, the Chelsea Water Co. of London, built, through their engineer, Mr. James Simpson, what was probably the first filtration plant for public supply. Simpson's idea was to strain water through sand and his only object was to remove silt. In 1855, the City of London compelled the other companies supplying water to it, to filter their water. The filtration of water through slow sand filters, although comparatively recent practice in America, has long been a standard universal practice in both England and the Continent. In 1904 France had sixty-one cities using this system. Our earlier filters were a copy of the European standard of practice, but of late, we have made many advances.

America's first attempt toward filtration dates from 1869, when St. Louis, seeking to improve the quality of their supply, sent J. P. Kirkwood to Europe to investigate their methods of purification. His report is the classic in the American literature on that subject. It received but little attention here at that time, but was translated extensively in Europe.

In 1872, Poughkeepsie, N. Y., built the first slow sand filter in America. Hudson, N. N., followed closely in 1874. The Albany, N.Y. plant built in 1899 under the direction of Allen Hazen, represents the most modern type of slow sand filter. At Altoona, the

ultimate rate of filtration has been doubled by the use of a preliminary filter. This removes most of the suspended matter but produces an inferior quality of water. The main filters receive this water and are able to pass it at a higher rate and with less clogging. The preliminary filters clog often and are cleaned by reversing the flow of water.

At Philadelphia, the Maigen filters have the same purpose. Shredded asbestos is spread over the surface of these small preliminary filters and when the filters become clogged, the asbestos is rolled off and a fresh lot spread on. In Europe, scrubbing is also resorted to. In this, the water passes through layers of gravel of decreasing size beofre reaching the filters, the larger particles in the water being removed.

Large plants are now under construction at Pittsburg, Pa., Philadelphia, Pa., Washington, D. C., and Detroit, Mich. Minneapolis, Minn., New Orleans, La., and Columbus, O., have the subject of filtration under consideration. It has been asserted that New York will ultimately have to filter her Croton supply.

Mechanical filters differ chiefly in the rate of filtration, being on the average forty times faster than the slow sand. Where the latter will attain a rate of three million gallons per acre per day, the former will attain a rate of one hundred and twenty gallons per acre per day.

Their main feature consists of adding the proper chemical so as to produce a floculent precipitate in which some of the impurities of water chemically form a part. The water thus treated, is

allowed to settle by passing it through a properly baffled basin at a slow rate. The floculent precipitate in descending, entangles most of the suspended matter including the bacteria. The comparatively clear water then onto the sand of the filters, through them, through a strainer, into the proper collecting system, and into the clear well. It is the precipitate of the water in this case, that forms the film. The filters clog in from six to eighteen hours, and are cleaned either with mechanical raking, or air combined with a back flushing of water.

Alum and copperas are the two main chemicals used. In using the former, the water must have an alkali reaction.

With the addition of alum, aluminic hydrate is formed. Sulphates of the other bases take care of part of the alum.

With the addition of copperas (iron sulphate) ferrous hydrate is formed. Lime must be added so as to neutralize the CO_2 in the water, and that set free by the iron salt combining with the carbonate of the water. Without the addition of the lime, the CO_2 would render the hydrate soluble. If the water has not enough alkalinity (usually five parts in one million) soda is added to it before th alum. The alum is added and some provision is made for a thorough mixing either with stirring rods, or air, or in some natural method.

With the copperas, the lime is added just after the copperas, and the same provisions are made for mixing.

Both the alum and copperas are dissolved in small tanks by air or stirrers, and are run into larger tanks and diluted to the required degree. This large tank feeds to an orifice tank keeping

a constant level therein. The discharge of this tank is varied by changing the size of the orifice. The amount of chemical fed by this tank depends upon the size of the orifice and the strength of the solution. For a sudden change of chemical feed, change the size of the orifice; otherwise change the strength of the feed.

The same general principles hold in the addition of the soda and lime, except that with the soda, the same care need not be taken as with the alum.

Chemical feed pumps are used in Louisville, Ky., instead of the orifice tank; in other places, a chemical inlet arrangement is regulated by a propeller in the raw water pipe whose speed (and consequently feed) varies as the velocity.

The mechanical filtration of water supply is but a development of the filtration for manufacturing purposes. In its first form, sedimentation and filtration were carried on in the same tank. The water was fed to the lower part of the tank and on its way, was charged with the chemical. In the tank, it took a circuitous path beginning at the outer circumference and passing upward at the center into the top of the filter above through it and to some convenient well. To wash the filter, clear water is forced backward and rakes revolving about the center of the tank and extending through to the bottom of the sand, thoroughly agitate the latter.

The containing tank has generally been made of wood and at times, of iron; lately in India, reinforced concrete has been used.

The most recent development in mechanical filters is exemplified in the East Jersey Water Co's plant at Little Falls, N.J. and plant at Hackensack, N.J. The coagulation basin is separate from

the filters, one basin supplying all the filters. The tanks are rectangular and built of reinforced concrete. Air, under pressure, takes the place of rakes in the older design. The air is delivered in small one inch pipes laid on the bottom of the filter, being independent of any other system. In the first designs of this new type, the air was delivered through the collector units, following the course of the wash water, or the clear water drain.

The very latest design embodies the use of a concrete collector system, it being cast in a skillful fashion in cast metal moulds. Gravel has also been used over the strainer system so that larger holes could be made in the latter.

The rate of filtration in each filter, is regulated by what is known as a controller. Two types that are most used now are the Western Controller and a modification of the floating weir. In the latter, the water enters a chamber from the filter by passing through openings in the conveying pipe. A ring slips by these openings on the inside of the pipe so that at one extremity of their travel, the holes are closed, while at the other, the holes are wide open. This ring is attached to a float and rises and falls with it. To this float is also attached a circular weir, sliding into another pipe that feeds to the clear well. The float keeps the head on the weir constant, and consequently, a constant discharge occurs. As the float rises, the rings close the openings in the supply pipe which is the discharge of the filter. The rate which has been increasing, will then decrease.

The greatest advance has been made in the plant as a whole.

Filters that are now built, are arranged to have semi-automatic apparati. Few valves now are actually turned by hand, hydraulic power being used. The whole filter is controlled from a stand in the room above each filter. The rate of filtration can easily be changed; signals announce when a filter has stopped; samples can readily be taken from the filtrate of each filter. The waste of the wash water is conveyed to the operating stand above the filter, passing through sight tubes (glass tubing) by which the degree of washing is noted.

In the operation, the water comes onto the filters by overflowing, and passes through the film, sand, gravel, and into the collectors. From these it passes through the controller and into the clear well. When cleaning is necessary, the supply is stopped, and wash water (filtered water) is forced back through the collectors, the gravel, and sand, and overflows into a system of drains. The main drain is connected with a waste pipe that leads to the sewer. The water is allowed to run for a few minutes, is then shut off, and the air under a pressure of 3# per square inch, is turned on. As it bubbles up through the water, it causes the sand grains to grind among themselves and seemingly to boil. It is found that this does not rearrange the grading of the sizes. The water should stand high enough so that no sand is ejected above it by the action of the air. This air may be supplied by a centrifugal fan directly, or by high pressure reservoirs through reducing valves.

The air and water are applied alternately until the waste water is as clear as the filtered water. The water is allowed to stand on

the sand so that the oncoming raw water does not strike the sand directly.

There is one kind of mechanical filter known as the pressure type in which the water is forced through the sand by pressure. The filters usually have the appearance of boilers. There has been little development along this line. The principle of the filter is wrong, in that, to carry it out, the whole process of filtration must be sealed, and one cannot see what is actually going on inside of the filter. Little attention has been given to these filters by the writer.

In investigating the proper means of purification of a supply, a careful study should be made. It is not for a council or a board of commissioners to decide whether they want mechanical or slow sand filters. In the case of large installation, actual experimentation should be carried on, and on a liberal scale. In this way only, can it be found how best to overcome the existing local contamination.

In many cases local conditions may decide which should be used. Thus, there may not be enough existing space for a slow sand filter and a mechanical filter must be used.

The recommendations above result from successful attempts at Louisville, Cincinnati, Pittsburg, New Orleans, La., and Columbus, O. To these experiments as well as those carried on at Lawrence, Mass., are due most of our knowledge of the mechanical filter. They show that, with careful and faithful management, results, nearly, if not fully as good, can be obtained with them as with the slow sand.

They will reduce certain colors where the slow sand fails; they will more successfully treat high turbidity than the latter.

On the other hand, slow sand filters do not need the skilled attention that the mechanical filters need. They can stand neglect with better results than the mechanical filters. The operating expenses in them are smaller than in the mechanical filters although the latter require less first cost.

The names given to the two principal methods have been slow sand and mechanical. Quite a discussion has arisen as to the proper appellation of each. It is the writer's opinion that English for the first, and American for the second is proper. The two types have originated in these respective countries and even though each is used extensively in other countries, there is little harm in using these names. On the other hand, the filter which is called slow sand may have its speed perceptibly increased, while that which is today called the rapid, may have its speed decreased. Would it still be proper to call the former slow sand?

Again the American filter has been called mechanical because of its method of cleaning, especially in the use of the rake. Supposing some mechanical means of scraping were to be introduced in the English filter, would it be proper to call it mechanical also?

They could hardly be called plain and chemical filters, for in some English filters, coagulent is used.

With these considerations, it is thought best to call them English and American filters.

GENERAL DESCRIPTION OF PLANT.

Note:--

It must be borne in mind that the accompanying drawings, especially those not dimensioned, represent a general sketching of the component parts. Dimensions have been left out purposely, for one reason, that details, which have not been worked out, might change some general dimension; and for a second reason, that some dimensions, as the size of the concrete columns or walls could not be figured until the data, which the design of the plant gives, could be obtained. In many cases then, the members are out of proportion. But those members whose size had been difinitely decided, were drawn to scale. The scale of figs. 9, 10, 11, 12, and 13, is 1-16" to 1'.

Some of the conventions of draughting have been disregarded in the interest of simplicity, clearness of presentation, and speed in the execution of the drawing. Thus, sections have been passed at random; complicated sections broken out; cross-hatching has been used instead of the familiar concrete section because it is difficult to show the intersection of different sections in the latter. In some cases where pipes enter or leave reservoirs, or the like, the line which is to represent the orifice on end of pipe, has not been drawn.

Symmetry in representation has been avoided so that

no repetition of figures need be made. Everything has been done to reduce the draughting to a minimum. No time has been spent to make the drawings tasty, some curves being sketched where instruments could have been used.

It was thought sufficient to show windows in section only. The convention for a window is a line at the middle of a space in the wall section. A door is represented by a line inclined to the given wall. Two inclined lines sloping toward each other represent a double door.

To aid in the description of the plant, certain locations are numbered. They do not represent any specific point but are intended to guide the attention to a certain locality. Hence we may have two or more points designated by one number. An expression as point 46-(12) means that that point 46 will be found in Fig. 12. Or again, point 105-(9) means that point 105 will be found in Fig. 9. They may be read as "point 46 in 12," or "point 105 in 9." A change of position of the different views after their first location in the tracing cloth, has caused the present jumble in their figure titles.

In the description that follows, with but few exceptions, no reasons or size of members are given because, in the first case too much diversion would occur, while, in the second case, when the design of these members are reviewed for the last time, some change might be made. This review will occur in the writing of the

section "Discussion of Filtration Plant," which will be written most likely after this has gone to print. Upon the completion of this latter section, topics or members upon which a discussion or dimensions are desired in the reading of the "Description" may be here found, marginal titles, or the like, facilitating the finding of the desired topic or member. It is expected that much that has been said in the "Description" will be repeated in the "Discussion."

The proposed plant is to supply filtered water and electric light to the towns of Fort Sheridan, Highwood, Highland Park, Ravinia, Glencoe, Lakeside, Winnetka, Kenilworth, and Willmette, all of which are in Illinois. These towns all border the shore of Lake Michigan. Glencoe has been the town chosen for the location of the plant. The mechanical type of filter has been selected, and with it are to be housed, the sedimentation basin, clear well, wash water reservoir,pumping station, supply well, electric generating room, boiler room, and coal storage. The plant is to be built at the foot of the lake bluffs two blocks south of Central Av.

The building is of reinforced concrete and may be considered as consisting of three compartments. One is 90' x 62' and three stories high. The first story containing the boiler room, with a simple set of coal handling apparatus, the electric generating room, the inlet or supply well, and a pump and air compressor room.

The second floor cantains the chemical mixing room in which are the compressed air reservoirs, the controlling board of the filter plant, the general office, chemical and bacteriological laboratory, baths, toilet, and locker room, and part of the coal bunker. The third story contains the top of the coal bunker or storage room, the chemical storage room, and a repair and work shop which will not only take care of the odd jobbing of the building, but also the consumers' water-meter repair, and like work connected with the maintenance of the supply system.

The second compartment is about 75' x 62' and also three stories. The first story containing a part of two clear reservoirs and the lower part of the pipe gallery. The second story contains the upper part of the filter operation gallery and the filter room. The third story contains the wash water reservoir.

The third compartment is about 53' x 105' being but two stories high. On the first floor are the other parts of the clear wells previously mentioned. On the next floor is the coagulating basin. The building is so placed that the general office faces to the Lake.

At 1-(13) is shown the entrance of the inlet pipe into the supply well; through an error it is not shown in Fig. 9 in which it should run from the point 92-(9) horizontally through the side wall. At 92-(9) the alum or copperas is fed to the water. At 2-(13) this water is drawn by the suction pipes of the centrifugal pumps at 93-(9) where it is churned. In passing 91-(9) it has a charge of lime added to it. Were soda to be used (in connection

with alum) it would be added to the water just after entering the building. The pipe conveying the treated water runs along the floor, passing through the wall of the clear well, and, when at the middle of this, it rises upward through the floor of the coagulating basin. At 90-(9) is shown its plan on the floor of the clear well; 13-(13) shows its vertical projection, the pipe resting on the floor of the coagulating basin; 54-(10) shows its plan in the coagulating basin. The water then traverses the length of the coagulating basin, passing against, and through the necessary baffle boards.

At 56-(10) is shown the plan of the perforated collecting tee, the elevation 28-(13) showing this tee to rest on the floor of the basin. At 57-(10) this pipe, conveying the treated water to the filters, rises above the floors and pierces the wall of the coagulating basin. At 58-(10) it dorps beneath the level of the floor of the filters, 25-(13) and 26-(13) giving a fair idea of this.

At 50-(12) is shown an elevation of the reducer through which the supply pipe feeds the filter, and at 65-(10) is shown the plan in which the water enters the waste pipe and (referring to 52-(12)) into the central drain channel of the filter. The water so fed rises to the top of the water already in the box. It is then ready for its descent through the sand.

The centrifugal pumps at 93-(9) have a valve on each so that either or both may be shut off (this is a protection against turbine action if one pump were shut off by merely stopping its motive power while the other was still pumping).

At 99-(13) there are two valves, one controlls the supply to the coagulating basin so that if this is shut, the basin can receive no water. If the other valve is opened the treated water will pass into this pipe lying on the floor to 102-(13) where it rises through the floor above, as is shown in Fig. 13 in which the pipe is traced from the pumps to its course, along the pipe on the floor above, to the point it enters the feed pipe at 25-(13). A plan view is shown at 58-(10) where the pipe enters the increaser. The valve of the feed at this point being shut, no water can be obtained from the coagulating basin. We get our supply then direct from the pumps, we having here what is known as a cutoff.

Following the water as it passes through the sand and gravel, we have it collected by the strainer system shown at 70-(10). In Fig. 1 we have a detail of the block. Fig. 5 shows the strainer in place which supports the gravel. The end section in Fig. 2 shows how the water, after collecting in the well of the hopper-shaped segment, discharges into the channel of the block which in turn, discharges into a main collector channel as shown to the right end of Fig. 2. At 71-(10) is shown the complete system in which the dots indicate the wells feeding into the channel and the channels into the main collector. At the center of this collector is a pipe which drains the latter. Point 67-(10) gives a better plan view of this pipe. The water from the four pipes similar to this, is collected by the single pipe which runs from a point beneath the center of the tank to 68 (10) from which it runs to a point beneath the filter regulator. It is shown passing into this box at 47-(12)

through the regulator (not shown) and out at 48 (12) from which it goes to the loop arrangement shown opposite 78-(10). The point 78-(10) shows one half of this arrangement, 61-(10) shows the other half. If the valve on one side as at 66-(10) is closed and that on the other half is open, then the water will pass into the reservoir or well on the right hand side. If the valve on the other side is closed as at 61-(10) and the opposite valve open, then the water will flow into the left hand reservoir. It is apparent that if both valves are open that the water will flow into both reservoirs at the same time.

The water for washing the filters is obtained from the reservoir shown in Fig. 11. At 96-(9) is the centrifugal pump which supplies this reservoir. Points 5-(13), 6-(13), 7-(13), and 23-(13), show the accompanying piping. At 111-(11) is shown the ectrance of this pipe into the reservoir after rising from 106-(9). The water leaves the reservoir by 112-(113) shown again at 24-(13), and passes downward to 29-(13), shown in plan a little above 59-(10). This pipe runs to the end of the row of filter boxes and is shown passing to one at 68-(10), entering by the arrangement at 67-(10), following exactly the reverse course of the filtering water.

The reservoir may also be supplied by the force main by closing the valve opposite 96-(9), and opening the one just past the end of force main only far enough so as to carry the water up the reservoir. The reservoir may be bypassed and the main wash-water pipe of the gallery supplied by the centrifugal pump by closing the valve at 7-(13) and at the end of force main, having that at

30-(13) and opposite 96-(9) open. We may bypass also by using the force main, in which case the valve on the end of the latter is open as is that at 30-(13), the valve opposite 96-(9) and that at 7-(13) being closed. The pressure of the water of the force mains may be reduced by the valve at the end of the pipe, or at 30-(13), or by both.

As the water emerges from the sand, it overflows into the sub-gutters shown in end elevation at 53-(12), the whole arrangement being shown in plan at 69-(10). These gutters feed into the central longitudinal gutter shown in elevation at 52-(12). From there, the dirty water is taken by a lateral of the waste pipe shown at 51-(12) and again at 77-(10). This waste water pipe lying on the floor of the filter room runs the length of the gallery, turning at the upper end so as to avoid the treated-water feed pipe (which at this point descends beneath the drain pipe) and continues to the middle of the space between the last filter and the coagulating basin wall.

It runs along the space out of the filter room piercing the floor and then turning slightly so as to get away from either wall, drops down to the catch basin at 97-(9). Fig. 13 gives the end elevation of the latter arrangement. In this elevation, at the point where the waste pipe pierces the floor, is seen a small pipe entering the elbo. This pipe runs the length of the hallway hugging the wall and enters the gutter 32-(13) which gutter drains by 33-(13) into the waste pipe 11-(13). In Fig. 10, we have this in plan, the small pipe being broken off before reaching the elbo so as to avoid confusion in the drawing at this point. The gutter is shown in the

the drawing at this point. The gutter is shown at 88-(10) being placed before the switchboard controlling the operation of the filters. The object of these gutters is to sample the waste water so as to note the degree of washing.

The air used in agitating the sand is generated in the compressors shown at 94-(9), delivering the air to the set of tanks shown in plan at 82-(10) and in elevation at 34-(12) where the air enters at the bottom of tank, and leaves at the top.

The piping from the compressors to the tanks has been omitted so as to avoid confusion; its arrangement can be worked out easily. The pipe running in front of the tanks at 82-(10) is the feeder from which any one tank, any two, or all three tanks may be filled. The forked arrangement of pipes is the outlet and the supply may be drawn in the same manner from any one, any two, or the whole three. The dotted figures represent future installation of tanks(in accord with the expansion of plant) in which case the outlet pipes would enter the main outlet pipe separately as in the present installation and in the same way, the supply pipe would extend to their front.

These tanks in supplying air to the filters have their pressure cut down by a valve in the gallery shown to the left of 42-(12). The supply pipe for the filters runs down the room to about its center being high enough so as to avoid all obstacles in the room. It then crosses and pierces the wall of the filter room and enters the gallery at 76-(10). The elevation is shown along 42-(12). At this point also is shown the feed into the filter.

The writer is better able to explain by starting with the dis-

charging end of this air system. In each half of the filter box lie eight 1" pipes connected at each end with a 2" pipe. At the middle of this 2" pipe and rising up to the level of the main waste channel is a 3" pipe which crosses over and joins with a similar 3" pipe to a 4" pipe which runs along the top of the main channel, meeting a similar 4" pipe from the other end of the box. Both these pipes are fed by a 6" pipe (the size of the main feed). We have then, one 6" pipe feeding two 4" pipes; one 4" pipe feeding two 3" pipes; one 3" pipe feeding two 2" pipes; and one 2" pipe feeding four 1" pipes for a length equal to one half of the box. Points 75-(10) and 43-(12) show the arrangement in plan and elevation respectively.

The valves of the filter are controlled electrically from the switchboard at 88-(10) or 31-(13). All valves in the plant including these, have arrangements so that they may be conveniently operated by hand.

The operation of the filters is as follows: The water is fed from 50-(12), passes through valve and into the box, the valve at 51-(12) being closed. The water passes through the filter and through the drain pipes into the controller, the valve at 46-(12) being closed and that below 47-(12) open. In order to wash, the valve at 50-(12) and the one below 47-(12) are closed, that at 51-(12), and at 46-(12) are opened. The water passes from the wash water feed pipe at 46-(12) up through sand and out at 51-(12). All valves are then closed and the air inlet valve shown at the right of 42-(12) is opened. The wash water and air are used alternately

finally ending with the water. Water stands upon the sand when the treated water enters to be filtered.

The clear well is divided into two compartments as has been previously indicated. At 103-(9) and 104-(9) are shown pipes which act both as a suction for the service pumps and drains for the wells. A section of the pipe draining the left clear well, is shown at 10-(13). Should the valve at 9-(13) be closed and that at 4-(13) be opened, the pumps will draw from the well. Should the valve at 4-(13) be closed and that at 9-(13) be opened, then the water of this well will be wasted into the catch basin. The design is such that either well can be drained while the other feeds the pumps, or both can be drained at the same time, or the pumps can be supplied from one or both.

The drain for the coágulating basin is shown in plan at 55-(10) a valve controlling each end of the basin. When the water for some reason, is required to take a new course, that section between the posts where ne movement occurs, can be drained. This water is carried to the vertical waste pipe 11-(13) entering it at 12-(13) beneath the elbows and is carried to the catch basin. Points 14-(13) and 15-(13) show these pipes in elevation, being dotted on account of an intervening wall.

The wash water reservoir is drained by closing the valve that leads to the gallery feed pipe near 59-(10) and opening the valve that leads to the waste water pipe of the filters. The entrance to the latter pipe is shown at 60-(10). Provisions are made at the switchboard for closing this valve when washing takes place.

Provisions for draining the chemical tanks will be spoken of later. All cement floors as in boiler room, engine room, etc., will have a floor drain which, in some cases, will pass to the catch basin but in such a manner as not to mingle with the water sampled and brought before the switchboard. In other cases, these drains will connect with the sewerage system of the building. There may be times in which it is desirable to drain certain of the pipings. By placing small faucets in the pipes to be drained, their liquid can be conveyed to some nearby floor drain by hose attached to these faucets.

The water in the catch basin discharges into the Lake by the large pipe 101-(9) or 37-(13) which runs in an open channel covered by a suitable grating or removable cover.

This channel, the ones in the clear well, and the supply well are perhaps the only parts that cannot be directly drained; in any case a small hand pump can be used.

The service pumps at 95-(9) get their supply from the clear well as previously described, forcing their discharge into the pressure main 107-(9). At some future period there may be a complete shut down of the filters due to some accident; for this occasion, a bypass to the forct pumps is provided so that they may draw and supply raw lake water. A part of this suction pipe is shown at 3-(13), the plan being shown opposite to 92-(9).

The centrifugal pump 96-(93) supplying the wash water reservoir draws its supply from the same pipe that the service pumps draw from.

The crude chemicals are received in barrels, the storage room

being indicated in Fig. 11. The hopper at 109-(11) holds the copperas, while that at 110-(11) holds the lime. In the section at 17-(13) is shown the slide which controls the feed of this chemical into the weighing box 18-(13) resting on the scale. The required amount of chemical being weighed, the box and scale are moved along the track 87-(10) until opposite the required tank when the slide at the end of the box is drawn, the chemicals slip out. One box is to be used for copperas while the other is to be used for lime, but, if at any time one scale would be rendered useless, the other scale could run to either hopper or any tank without interfering with the idle scale.

The tank at 85-(10) and the one above it are the solution tanks. Either discharge into the tank at 83 or the one above it. The latter may be called the dilution tanks. They feed into a pipe shown at the right of the tanks by means of which the solution may be drawn from either tank. From a tee at the center of this pipe, the dilute chemical is conveyed to the point of feed at 92-(9) where it passes through the feed controlling apparatus and into the raw water supply well. The piping to this apparatus and the latter itself, are not shown. At 20-(13) and 21-(13 are the elevation views of the solution and the dilution tanks respectively. At 19-(13) is the elevation of the lime tank. In this, the solution and dilution tanks are combined, the first above the second. A centrifugal pump 22-(13) raises this solution to 108-(11) or 16-(13), the feed controlling apparatus, from which point it is conveyed to 91-(9) and here discharged into the water.

In mixing the chemicals, sufficient filtered water is placed with the measured amount of the former to allow solution. To aid the dissolving, the water is agitated with air, a system similar to that at 86-(10) being used in all tanks. When complete solution has taken place, the contents of this tank, are let into the larger tank where the solution is diluted to the required degree, followed by a thorough mixing by means of air.

The pipes supplying these tanks with filtered water are not shown. The drain of these tanks does not appear. They are to be small vitrified pipes hung upon the ceiling of the first floor, entering 11-(13) below the elbows and above the coagulating basin drain. Whenever these tanks are to be drained, the waste pipe is to be flooded with water from the wash water reservoir.

The boiler room is situated on the first floor shown in Fig. 9. Coal is discharged by the chute at 36-(12) controlled by the slide at its bottom) into a small dump car which runs on a track and delivers the coal in front of any boiler as 39-(12).

As for the electric generating room, little can be said, for the power to be generated, and the type of engine has not, at this writing, been decided upon.

The general office, chemical and bacteriological laboratory, baths, toilet, and lockers are situated on the second floor. Their general furnishing will be of a moderate but modern character.

The floor of the filter room extends to the pipe gallery as is shown in the unoccupied part of the room or beneath the broken section of the operating gallery floor. The operating gallery floor

extends across to the filter boxes on each side, being four feet below the level of them. Resting on this floor are the wheel stands for the hand operation of filters. The floor runs half of the length of the gallery or just past the occupied section of the room. Descent is made to the pipe gallery by means of a temporary wooden stairway. When the filter room is fully occupied, this stairway will be removed and replaced by a permanent one at the lower end of the gallery.

The floor of the gallery extends around the filter boxes at its upper end. The middle longitudinal section of this floor in the left hand hallway is removable so that repairs on the pipes below it, may easily be made. A stairway at the end of this hall leads into the hallway of the building. The trap door at 74-(10) allows entrance to the clear well beneath; that in the adjacent hallway allows entrance to the other clear well.

Entrance is made to the coagulating basin through its roof. The trap door being shown at 113-(11) arrangements are made within so that pulleys may be hitched above the various tiers of baffle boards by which the latter may be placed or withdrawn. Pairs of gang planks suspended from the roof allow access to all tiers of baffle boards and to other important points in the basin.

Entrance to the wash water reservoir with a ladder built into the wall is shown at 41-(12). The roof doors for the admission of coal is shown above the bunkers.

Stairs connecting the different floors are shown against the middle wall of Figs. 9, 10, and 11. In the first figure or Fig. 9,

the space occupied by the stairs is only indicated. The lubricants and various engine sundries, may be placed from beneath these stairs to the clear well.

PARTIAL CLOSURE.

The subject chosen had not been worked upon long before it became apparent that that there was enough material in it for two theses of the size of the first contemplated, and of the same manner of treatment. In the reading of this thesis in its present form, it may first appear that too much time has been spent upon the preface and introduction so that they overbalance the subject in hand. This is very probably true so far as this thesis has gone; but considering that this is but a first part and that from ten thousand to twenty thousand (or probably more) words will appear in the second thesis, it is seen that this preparation is none too extensive. At present the writer has over three thousand words in jotted note form that have not appeared in this thesis. They relate mostly to the subject of filtration as so far covered, being arguments and calculations for the parts used.

Some of the subjects that will be treated and which have not been mentioned before, are:

INTAKE--Location and type of.

DESIGN OF SOME GENERAL DETAILS OF FILTER PLANT.

DESIGN OF SPECIAL APPARATUS OF FILTER PLANT------
(Copperas Control
(Lime
(Filter regulator
(Switchboard, etc.

REINFORCED CONCRETE----
(Calculation of typical parts of building
(Calculation of typical parts of special apparatus.

FOUNDATION OF BUILDING.

PIER

ELECTRIC GENERATING PLANT.

STEAM POWER PLANT.

When these subjects are finished, then can it be decided whether or not to add more. The additions now in mind are Specifications and Cost.

One reason for incorporating an electric and steam plant in the thesis is that a civil engineer, from the writer's point of view, should have, at least, a primary knowledge of both. Engineers of the past have had to. Engineers of the present, as a rule, know little of either. But this does not prove that engineers of the future need not know them.

The plant as a whole, as designed by the author, depended upon a knowledge of the power plant. This has not been definitely decided, but an idea of the fixtures required were obtained so that the general design of the whole plant has proceeded with a fair amount of confidence. Economy is obtained when a town of, say ten thousand, can operate its filtration, pumping, and electric light plant under one superintendent and one corps of assistants, occupying one building with but one set of machinery. A civil engineer could hardly afford to hire a specialist to work in conjunction with him on as small a job as this. In such cases, a fair knowledge of the layout of a power plant is desirable. The writer has in mind a similar case that occurred to an engineer in actual practice.

No more time will be spent in arguing this point. The writer intends to make a fair study of these plants and in designing one,

expects to handle any ordinary problem that may, at a future time, occur to him.

The subjects taken up by the thesis so far and that which is to follow cover quite a range in Civil Engineering. It cannot be expected that they will be finished in a short time. Investigations have been carried on in most of the subjects and the writer could have, with little trouble, added the "Discussion of Plant" but he prefers to reconsider some subjects. Work on them is to be kept up at spare or leisure intervals.

The remaining part of the thesis here spoken of, is intended to be handed to the Faculty at such date when the writer is eligible to obtain his degree of"C.E." The "Appendix" mentioned in the "Preface" refers to this thesis.

This "Closure" is more in the nature of a progress report to the Faculty, and is to be replaced by one at the end of the subject of filtration, and one at the end of the final thesis. This "Closure" is purposely ignored in the "Preface."

F. E. VEY,
Huntley, Montana,
May 30, 1905.

Brass tube
inside

8"

Fig. 1

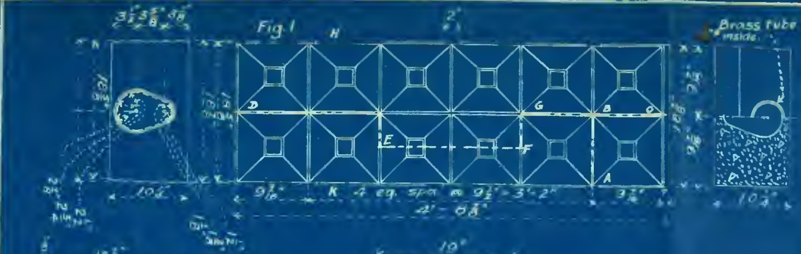


Fig. 2

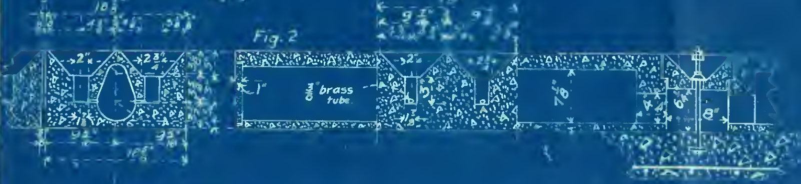


Fig. 3

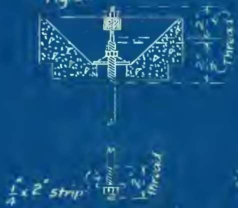


Fig. 4

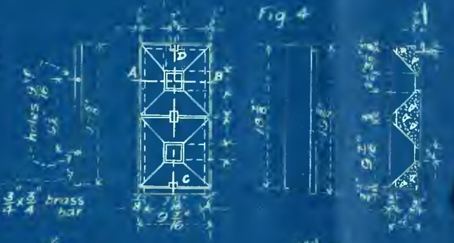


Fig. 5

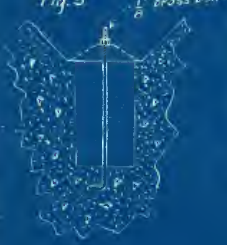


Fig. 6

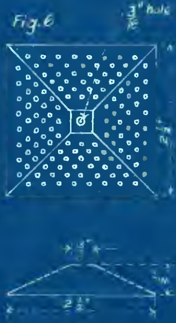


Fig. 7

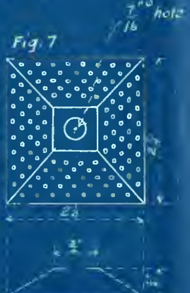
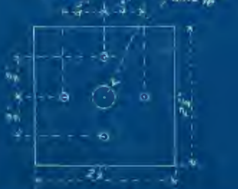


Fig. 8



Scale
Figs. 1, 2, 4 are 3" = 1'-0"
Fig 3 is 12" = 1'-0"
Fig. 5 is 3" = 1'-0"
Figs. 6, 7, 8 are 6" = 1'-0"

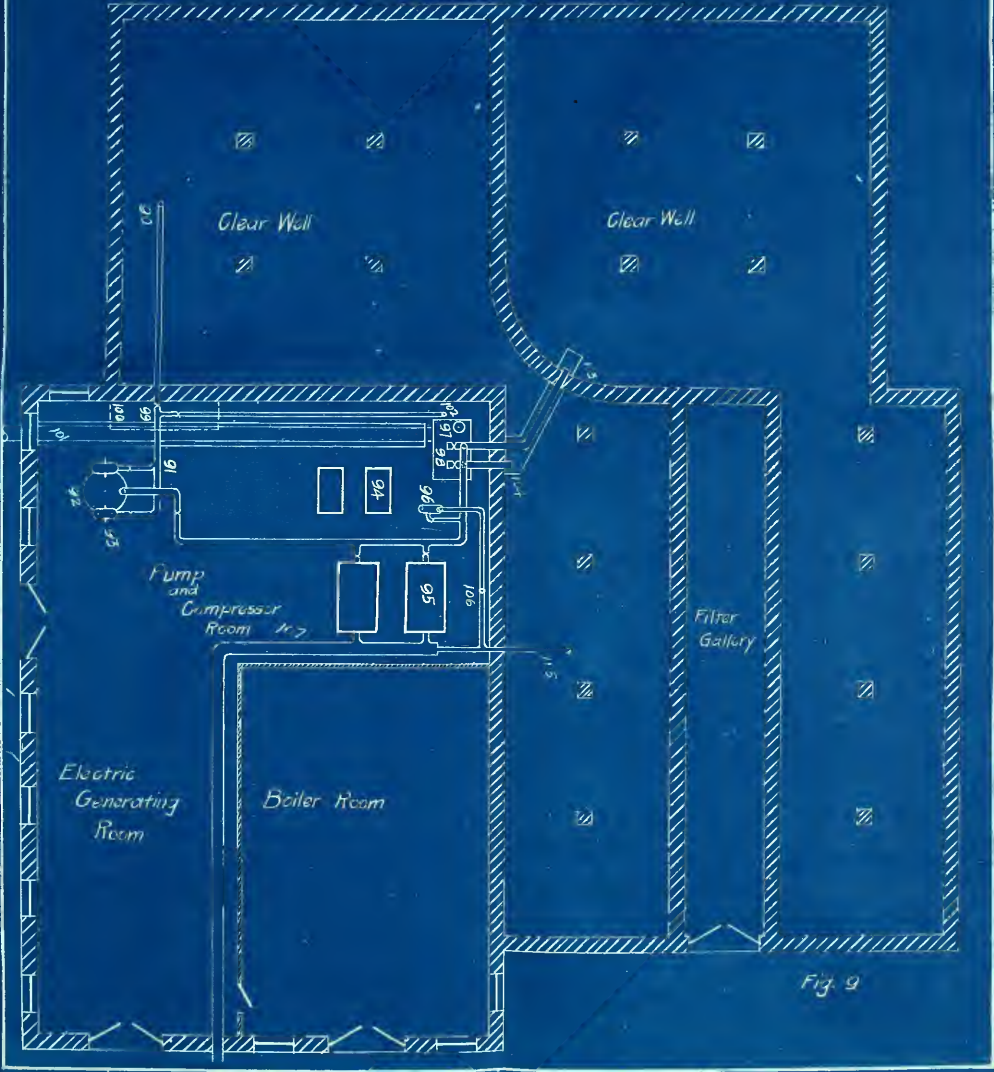

Clear Well
Clear Well
Pump and Compressor Room
Electric Generating Room
Boiler Room
Filter Gallery

Fig. 9

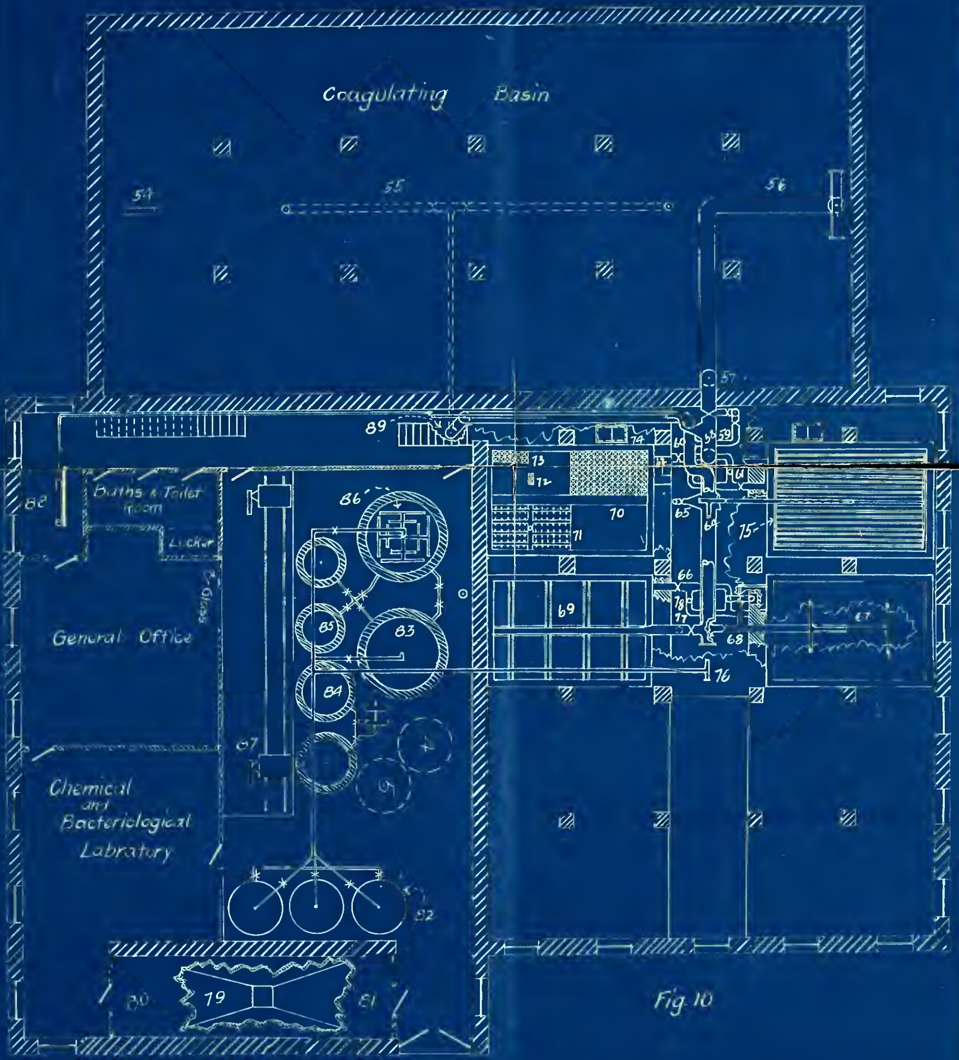

Coagulating Basin
Baths & Toilet Room
Locker
Glass
General Office
Chemical and Bacteriological Laboratory

Fig. 10

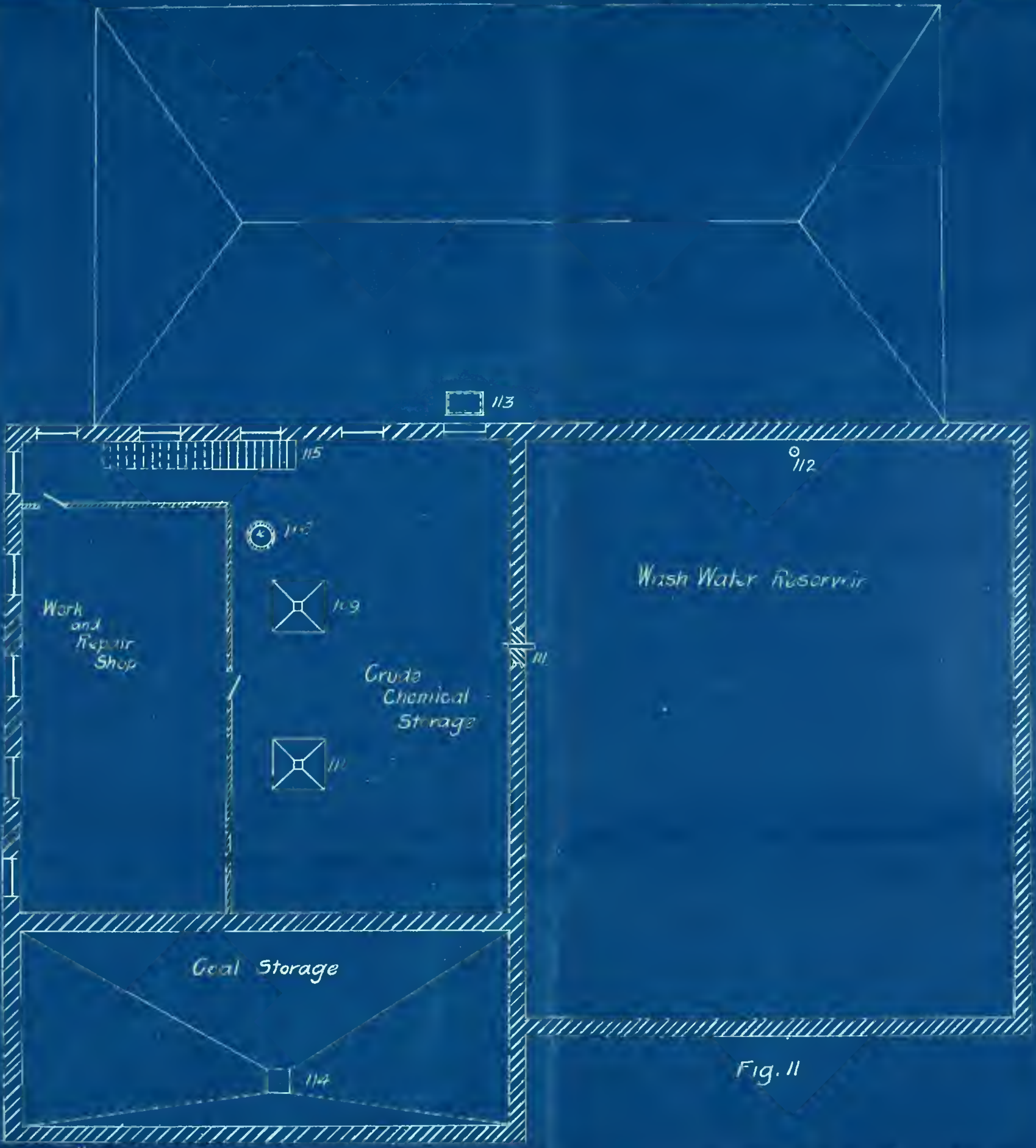

Work and Repair Shop
Crude Chemical Storage
Wash Water Reservoir
Coal Storage

Fig. 11

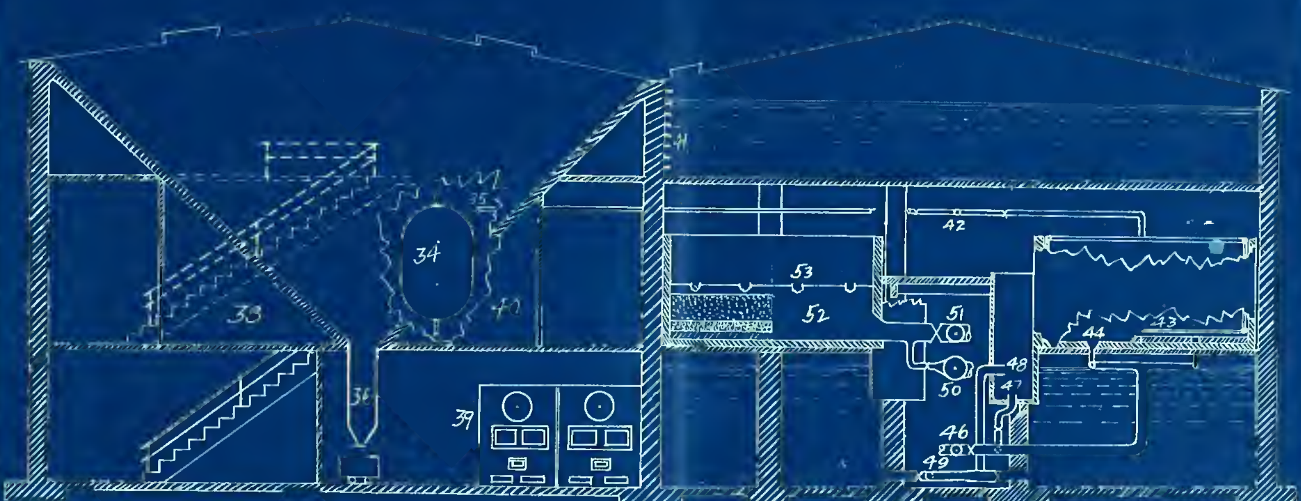


Fig. 12

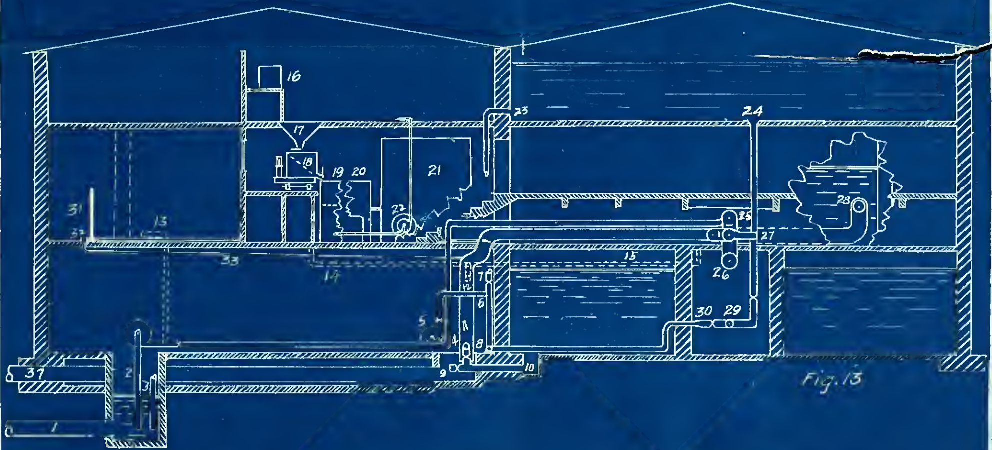


Fig. 13